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*A Systematic Review of Methods to Assess Metacognition in School-aged Children**

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Abstract

This paper presents the results of a systematic review of methods that have been used to measure or assess metacognition in school-aged children (4-16 years) over the last 20 years. Research focussing on different methods of assessing metacognition is increasingly important in policy and practice, particularly given the positive links demonstrated between metacognitive awareness, attainment and positive student outcomes. It includes an overview of the types of tool and methods used, linked with the ages of the participants targeted and how metacognition and associated concepts are defined. 2721 records were identified through systematic searching; 525 articles or reports were full text screened, resulting in 153 included studies reporting 86 distinct tools or methods. Of these five were excluded from further analysis after appraisal for reliability, validity and replicability. The final number of methods and tools for metacognitive assessment included in the analysis is 81. The key findings of this review include:

- Self-report measures (including questionnaires and surveys) are described in more than 50% of the included records;
- Observational methods have only been used with students aged 11 years and under;
- Information about reliability and validity is not always given or given accurately for different tools and methods;
- The definition of metacognition in a particular study relates directly to its assessment and therefore its outcomes: this can be misaligned.

Background

This article presents the results of a systematic review (Gough, Oliver, & Thomas, 2012) of methods that have been used to measure or assess metacognition in school-aged children (4-16 years). It therefore provides a synthesis of recent literature (1992-2012) in English focussing on the measurement or assessment of metacognition, with particular relevance for education.

Metacognition Research.

There is a wealth of research claiming to measure or assess metacognition, but the different methods have not previously been synthesised in a systematic way. Research focussing on different methods of assessing metacognition is increasingly important in policy and practice, particularly given the positive links demonstrated between metacognitive awareness, attainment and positive student outcomes (Akyol, Sungur, & Tekkaya, 2010; Higgins, Hall, Baumfield, & Moseley, 2005; Prins, Veenman, & Elshout, 2006). This systematic methodological review of methods therefore identifies the different tools and methods used to assess metacognition in the last 20 years and their reported reliability and validity, but aims to also facilitate an exploration of the potential links between:

- The types of tool or method used and the ages of the participants they are used with; and
- The tool or methods used and links between how metacognition and associated concepts are defined.

Metacognition and self-regulation.

Veenman's (2005) overview of assessing metacognitive skills provides a good introduction to this field. Since Flavell (1976) coined the term 'metacognition' there has been widening debate about what metacognition actually is and also how it can be assessed. The complexities of this have become increasingly clear over the last 30 years. Metacognition is something of a "fuzzy" concept (Scott & Levy, 2013) and when one digs below the surface of the popular definition *thinking about thinking*, there are many competing perspectives about metacognition and associated concepts such as self-regulation. These competing claims require a "multiplistic perspective" (Hofer & Sinatra, 2010: p. 117).

Confusion around defining metacognition and self-regulation, especially their intersections and links, is compounded by the fact that they are often used interchangeably in the literature and without adequate or explicit consideration given to their relationship (Hofer & Sinatra, 2010; Moseley et al., 2005). One issue, for example, is which of the two concepts is higher or broader when they are described hierarchically. Pintrich and De Groot (1990) assert that metacognitive strategies are included within the overarching concept of self-regulated learning. Similarly Boekaerts (1999) proposes a model with self-regulation as the major construct of which the use of metacognitive knowledge and skills is a part, but does not have the central role. Other researchers perceive self-regulation as something that is part of the broader concept of metacognition. Metacognition is popularly divided into two components: knowledge of cognition and regulation of cognition (Yildiz, Akpinar, Tatar, & Ergin, 2009) or meta-cognitive knowledge and skilfulness (Veenman & Spaans, 2005). Linked to this division, the regulation of cognition is described by Schmitt and Sha (2009, p. 256) as "…meta-cognitive control (or regulation), and includes problem solving at points of difficulty, monitoring the effectiveness of attempted action, planning one's next move and revising one's strategies if they fail to result in an interpretation that makes sense". There are clear links here between popular definitions of self-regulated learning and this definition of metacognitive control, which we would see as a component of metacognitive skillfulness. It is not the purpose of this review to arbitrate between these differences, but to note them and then be as transparent as possible about how different definitions and conceptions are related to the tools and techniques used to assess meta-cognition.

Research Question, Design and Methods

The central research question for this review is:

- What different research or assessment tools have been used to measure or assess metacognition in school aged children (4-16 years) in the last 20 years?

The main hypothesis being tested is:

- Different methods of measuring or assessing metacognition will be used and applied differently with different age groups.

The methods that have been employed in this systematic review are based on the PRISMA statement (Moher, Liberati, Tetzlaff, & Altman, 2009) which encompasses both meta-analysis and systematic reviewing. The rigorous nature of the PRISMA statement was adopted to maintain quality and integrity especially during the search and screening processes.

The focus of this review is on the tool or method stated by the authors as the measure or assessment of metacognition, as opposed to a more typical systematic review which focuses on the results or effects of a given metacognitive intervention or comparing the results of different interventions (Torgerson, 2003). Systematic methodological reviews to date lie mainly in the field of health and social care (e.g. Brandstätter, Baumann, Borasio, and Fegg (2012) who review 'life assessment instruments"; or Berne et al. (2013) who look at assessment instruments for measuring cyber-bullying). We felt that the field of meta-cognition was sufficiently broad and complex to justify a similar methodological review.

The search process

After defining the research question and thinking about the intended parameters of the search, pilot searches using key words and strings were completed in ERIC and BEI in order to refine the search strategy and to limit results to a manageable numbers of records for screening. Searches were completed for eight key databases: (AEI, BEI, ERIC, First Search ECO, First Search Journal Articles, PsychArticles, PsychINFO and Web of Knowledge). Detailed information showing the search strings used and limits applied can be found in Appendix A.

Inclusion criteria

In order to complete the screening process in a systematic and transparent way, clear criteria for the inclusion of records from the beginning of the review process were defined in relation to the research question and hypothesis. The inclusion and indeed exclusion criteria were based on the following categories:

- The date of record
- What is being measured in the record
- The sample population in the record
- An empirical data set being present in the record
- The language in which the record is available

Table 1 illustrates how these categories were applied.

Table 1: *Inclusion and Exclusion Criteria*

Category	Rationale	Inclusion criteria	Exclusion criteria
Date	A systematic review specifies a time scale within which records are searched for	Records published between January 1992-November 2012	Records published outwith January 1992 and November 2012
What is being measured?	The focus of the review is metacognition and closely related and defined concepts	• Record specifies it is measuring metacognition or a closely related concept and there is a clear definition of what is being measured • Measured in the first language of the participants	• Metacognition or closely associated concept not being measured or the definition of metacognition is not clear or clearly linked to the measurement outcomes • Not measured in the first language of the participants
Sample population (age, setting, normally achieving)	The sample population must fall within the defined age group (4-16 years) and be normally or average achieving in mainstream education in order that there is a degree of homogeneity in the samples for the different included tools or methods	• Participants aged 4-16 years (at least 50%) • Mainstream school • Cross section of students (average achieving or cross section of abilities)	• Participants not 4-16 years • Not mainstream school setting • More than 50% of students identified as having additional needs or being gifted
Data set and methodology	The record needs to include an empirical data set to be included[1]	Empirical data needs to be collected and there must be a clear and replicable tool or method	No empirical data or the methodology is not clear or replicable
Language of the record	Time and financial constraints did not allow for records to be translated if they were not readily available in English[2]	Record readily available in English	Record not readily available in English

[1] A systematic review is an iterative process and in effect the processes are defined by outcomes along the way. Therefore records that had been excluded early on as they did not contain an empirical dataset were added back in during data extraction. This happened if they were the first available record of a particular tool or method that other records used or referred to.

[2] Every reasonable effort was made to find out if a record was readily available in English, including making contact with authors.

The screening process

The screening process was lengthy, but rigour at this stage was important in order to maintain the integrity of the review process. Although an inductive process was adopted, i.e., responding to findings within the search and screening process, consistency was key and when decisions were made they had to be applied in the same way to all records.

The first author completed the first stage screening, for this stage the title and abstract for each record were scrutinised to see if they were on topic (i.e. about metacognition or a specified closely related concept like self-regulation) and that the sample was potentially in the correct age group (i.e. school aged, age 4-16 years). To calculate inter-rater reliability 20% of the 2089 original records were double-screened in the first stage screening by the second author, an inter-rater agreement of 98% was recorded. After this initial screening, the list of records classified as unsure were reviewed by all three authors. Individual records were discussed until consensus was reached. If there was uncertainty, records were included in order that they could be looked at in more detail in the second stage screening.

Second stage screening involved detailed full text screening; this focussed primarily on the methodology sections of the records because this information would be key in the next stage of data extraction. Based on the structure used by Dignath, Buettner, and Langfeldt (2008) the records at this stage were coded for the following variables in order to include or exclude them:

- The full reference details – for ease of reference and accurate record keeping
- A definition of metacognition – was this present, and clear?
- The sample characteristics – age group and educational setting
- Methodological information – was there clear information about the method or tool that had been used? Did it appear to be replicable from the information given?

Records were included, excluded or placed in an 'unsure' category and records classified as 'unsure' (n = 39) at this stage were subsequently double screened by the second and third authors. Records were discussed until all parties reached total agreement.

Data extraction and quality appraisal

Data extraction for each tool or method was performed using a template and completed from the earliest available record (with detailed methodological information) for each tool or method. In some cases this was a record that had been added to the total via citation searches. This mainly applied to records that would not have been picked up in the original searches due to falling outside of the specified dates. For example Jacobs and Paris (1987) is included as the first record detailing the Index of Reading Awareness (IRA) but was not initially identified through in the search process.

The template for data extraction for the 86 tools or methods in the final data extraction is illustrated in Figure 1. The data extracted in this example are for the Inventory of Metacognitive Self-Regulation (IMSR) first referred to in the data extracted records by Howard, McGee, Shia, and Hong (2000). Tools or methods were allocated to groups according to their methodological similarities (this classification in included in the summary table in Appendix B). For example,

which tools or methods are questionnaire based, or based on the completion of a particular task or set of tasks. These broad categories are listed below, it is important to note that tools or methods do not always exclusively fit into just one category.

1. Questionnaires, surveys, self-report
2. Task based methods and tests
3. Observational methods and teacher ratings
4. Interviews
5. Multi-method approaches

Method / type of instrument:	Inventory of Metacognitive Self-Regulation (IMSR)
First record full reference[1]:	Howard, Bruce C., McGee, Steven, Shia, Regina, & Hong, Namsoo S. (2000). *Metacognitive Self-Regulation and Problem-Solving: Expanding the Theory Base through Factor Analysis.* Paper presented at the American Educational Research Association 2000, New Orleans. http://search.proquest.com/professional/docview/62175370?accountid=14533
Definition of metacognition associated with original development of measure:	p. 1 "there are five particular metacognitive and self-regulatory constructs relevant to problem solving." And "our analyses indicate that the constructs measured by the IMSR are independent, and therefore a student may show preferences or "styles" of metacognitive strengths and weaknesses that depend upon his or her unique combination of constructs. If these "styles" can be further understood and delineated, it might be possible to train students to habitually use particular regulatory behaviors." p. 2 "Metacognition enables students to coordinate the use of current knowledge and a repertoire of reflective strategies to accomplish a single goal. Metacognitive awareness, therefore, serves a regulatory function and is essential to effective learning because it allows students to regulate numerous cognitive skills."
Aim of the study:	p. 2 "We began with the pragmatic goal of developing an instrument that would further our research and could also be used extensively in classrooms across the country to help teachers identify students' self-regulatory strengths and weaknesses. It was not our intention to replicate the work of our predecessors in this area. Instead, we wanted to develop an easy-to-use self report inventory for use with 12–18-year-olds that focused more specifically on metacognitive awareness and regulatory skills for solving mathematical and scientific problems."
Description of the tool or method:	• Focus on metacognitive awareness and regulatory skills • Phase 1 – based on JrMAI Version B and HISP (How I Solve Problems) inventory. • Phase 2 - "In Phase Two, our goal was to create a new inventory specific to metacognitive awareness and regulatory skills in the context of problem solving. To this end, we examined the 23 remaining items from the original two inventories and revised or rewrote them to increase reliability, and wrote additional items to clearly demonstrate the existence of the five factors that had emerged in Phase One." (p.2) • Particular emphasis on the importance of 'Knowledge of Cognition' • "The IMSR included 37 items with a five-point Likert scale. For each of the 37 items, students were instructed to circle the answer that best described the way they are when doing schoolwork or homework (1=never, 2=seldom/rarely, 3=sometimes, 4=often/frequently, 5=always)." (p. 4) Lots of links to the work of Swanson (1990)

Sample size (n):	**Age range:**	**Average age (if applicable):**	**Setting of study:**
829	Grades 6-12 (USA)	-	Schools, USA

Link to metacognition:			
Metacognition for something else (e.g. Mathematics achievement) ☐	Internally testing metacogntion (e.g. solely measuring this or an aspect of it). ☑	Testing the tool (e.g. assessing its reliability and/or validity) ☑	Extra info if applicable
Type of study:			
Pre-test, post-test ☐	Longitudinal ☐	Experimental ☐	Other: Unsure?

Reliability:	**Validity:**
"The overall inventory demonstrated a reliability of alpha=.935. We conducted an exploratory principle components factor analysis using a varimax rotation. The resulting solution revealed five factors with eigenvalues over 1.12, which accounted for 51.6% of the variance. Reliability for each factor ranged from alpha=.720 to alpha= .867. Table 1 shows the factors, their descriptions, and the factor weights above .40. In addition, Table 1 shows three items (asterisked) that weighed only moderately across several factors, or weighed heavily on factors different than those hypothesized. For future research we would recommend removing or revising these three items." (p. 4)	Face validity of the items in the inventory is discussed throughout as the items are selected and tested in the different phases.

Additional references:	**Extra information that they add regarding this tool or method:**				
	Setting of study	Changes to the tool or method	Link to metacognition	Type of study	Validity and/or reliability
Howard, Bruce C., McGee, Steven, Hong, Namsoo S., & Shia, Regina. (2000).	n = 1163 students Study focussed on the evaluation of an intervention using Astronomy Village software.	32 item inventory	Metacognition as a measure of learning. SR prominent in this study	Pre-test, post-test	Refers to validity in earlier paper.
Parcel (2005)	n = 140 2 schools 5th graders aged 10-12	-	Focus on metacognitive prompts and ability	Experimental	Current studies suggest IMSR has reliability alpha of .935
Howard, McGee, Shia, and Hong (2001)	n = 1502 students, grades 5–9, from schools across the United States	32 item inventory	One of the hypotheses is: "High levels of metacognitive self-regulation will compensate for low overall achievement, ability, or aptitude."	Pre-test, post-test	Refers to validity in earlier paper.

Figure 1: An example of data extraction for one tool (IMSR), the template shows data extraction from a total of four separate records found in the systematic searches

Results of the search process

Search results are illustrated below in Figure 2.

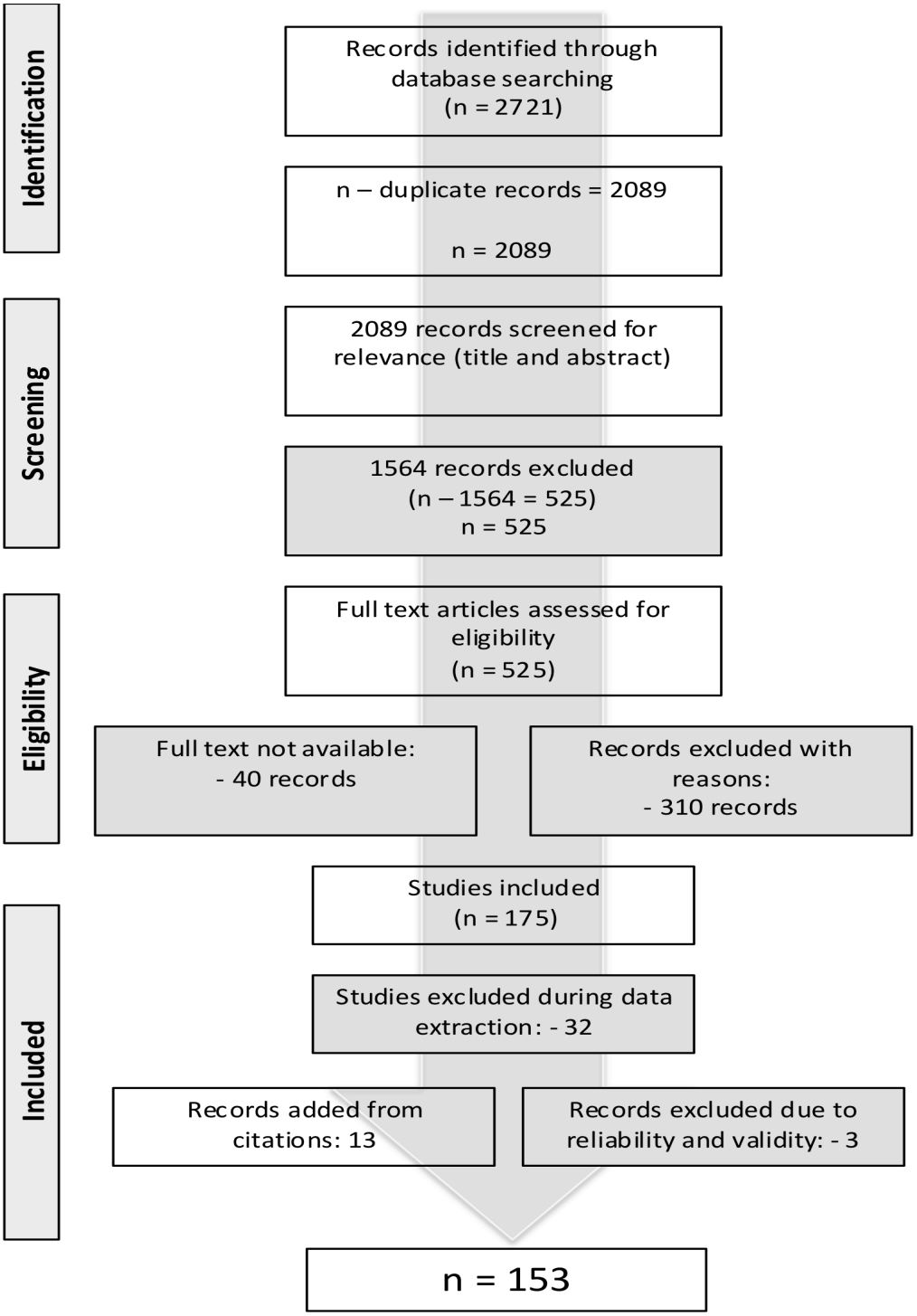

Figure 2: Flow diagram illustrating the numbers of records at different stages in the searching and review process (based on the PRISMA flow diagram: Moher, Liberati, Tetzlaff, & Altman, 2009)

Application of inclusion criteria

It was evident from the initial screening of the final included records here were multiple records to data extract for particular tools or methods. For example, Think Aloud Protocol(s) (TAP(s)) were cited as a method used in 14 separate records, the Index of Reading Awareness (IRA) and the Motivated Strategies for Learning Questionnaire (MSLQ) were individually cited in 10 included records each. Therefore, rather than data extracting from each of the 175 included records[3] they were summarised in terms of the tool or method that they used. Similar tools were data extracted concurrently, the method or tool that had been used was identified and data were extracted under the heading of the tool or method. Some records uniquely cited a tool or method, these records were data extracted individually.

Results of the quality appraisal

An appraisal of the reliability, validity and replicability appraisal of the tools or methods as part of the final data extraction was important, given the methodological focus of this review. Tools were excluded at this stage because they were not replicable (i.e., there was not sufficient published information to make replication possible), or because if replication was possible but there was not sufficient information given or available regarding reliability and/or validity.

What follows is based on Coffield, Moseley, Hall, and Ecclestone (2004) analysis of learning styles instruments. **Table 2** presents each of the 86 tools and methods included after the final screening; it indicates whether or not they are replicable and highlights the different types of reliability and validity reported. These have been divided into the eight most frequent main types in the included records:

- Reliability: Internal consistency, test-retest and inter-rater
- Validity: Construct, face, content, criterion and ecological

Some of the included records list ways of reporting reliability and validity data that are not reported in the above list. One example is that of parallel forms reliability Sperling, Howard, Miller, and Murphy (2002) focuses on testing two forms of the same tool in one experiment; the Junior Metacognitive Awareness Inventory (JrMAI), versions A and B.

Records were deemed replicable if they referenced other records that replicated the tool in part or full, or in the case of computer programmes if the method was based in a computer programme or a software package it was assumed that it could therefore be replicated through use of the software. Five tools or methods that did not meet the stated reliability, validity or replicability criteria were excluded at this stage and are shaded in the table

[3] 175 included records pre data extraction and quality appraisal.

Table 2:

The reliability, validity & replicability for each of the data extracted tools or methods (n = 86)[4]

	Reliability			Validity					
Tools or methods	Internal consistency	Test-retest	Inter-rater	Construct	Face	Content	Ecological	Criterion	**Replicable?**
1. Bandura's Self Efficacy for Self-Regulated Learning Scale	✓	-	-	✓	-	-	-	-	✓
2. CA (Child Assessment)	✓	✓	-	-	-	-	-	-	x
3. CDR (Cognitive Developmental aRithmetics test)	✓	-	-	-	-	-	-	✓	✓
4. Classroom Coding System	✓	✓	✓	-	-	-	-	-	✓
5. Clinical Interview (Erbas and Okur, 2012)	-	-	-	-	-	-	-	-	x
6. Clinical Interview (Pappas, Ginsberg and Jiang, 2003)	-	-	✓	-	-	-	-	-	✓
7. Computer based measure of metacognitive skilfulness	✓	-	-	-	-	-	-	✓	✓
8. Concept maps	-	✓	✓	-	-	-	-	-	✓
9. Conditional knowledge	✓	✓	-	-	-	-	-	-	✓
10. Constructivist Internet based Learning Environment Survey (CILES)	✓	-	-	✓	-	-	-	-	✓
11. EPA2000 (Evaluation and Prediction Assessment)	✓	-	-	-	-	✓	-	✓	✓
12. Epistemic metacognition measure	-	-	✓	-	-	-	-	✓	✓
13. General Studies Metacognitive Orientation Scale (GSMOS)	✓	-	-	-	-	-	-	-	✓
14. Goal Orientation and Learning Strategies Survey (GOALS-S)	✓	-	-	✓	-	-	-	-	✓
15. How I Study Questionnaire (HISQ)	-	-	-	-	-	-	-	-	x
16. Index of Metacognitive Awareness about Writing (IMAW)	✓	✓	-	✓	-	-	-	-	✓

[4] Where tools or methods have similar or the same names, primary citations are listed to aid clarity.

	Reliability			Validity					
Tools or methods	Internal consistency	Test-retest	Inter-rater	Construct	Face	Content	Ecological	Criterion	**Replicable?**
17. Index of Reading Awareness (IRA)	✓	✓	-	-	-	-	-	✓	✓
18. Index of Science Reading Awareness (ISRA)	✓	-	-	✓	-	✓	✓	✓	✓
19. Individual interview – strategy use and metacognition	-	✓	✓	-	-	-	-	-	✓
20. Integrated Learning Assessment	✓	-	-	-	-	-	-	-	✓
21. Interview about Metacognitive Awareness (IMA)	-	-	-	-	-	-	-	✓	✓
22. Interview from the Munich Longitudinal Study …	✓	✓	-	-	-	-	-	✓	✓
23. Inventory of Metacognitive Self-Regulation (IMSR)	✓	-	-	✓	✓	-	-	-	✓
24. Junior Metacognitive Awareness Inventory (JrMAI)	✓	-	-	✓	-	-	-	✓	✓
25. Knowledge and skills questionnaire	✓	-	-	✓	-	-	-	✓	✓
26. Learning strategies assessed by journal writing	✓	-	✓	-	-	-	-	-	✓
27. Learning Through Reading Questionnaire (LTRQ)	-	-	✓	✓	-	✓	-	-	✓
28. Metacognition Applied to Physical Activities Scale (MAPAS)	✓	-	-	✓	-	✓	-	-	✓
29. Metacognition of Nature of Science Scale (MONOS)	✓	✓	-	-	-	-	-	-	✓
30. Metacognition Scale	✓	-	-	✓	-	-	-	-	✓
31. Metacognitive Processes in Physical Education Questionnaire (MPIPEQ)	✓	-	-	✓	-	-	-	-	✓
32. Metacognitive ability self-report questionnaire	✓	-	-	-	-	-	-	-	✓
33. Metacognitive Attribution Assessment (MAA)	✓	-	-	-	-	-	-	✓	✓
34. Metacognitive Awareness Inventory (MAI)	✓	-	-	✓	-	-	-	-	✓
35. Metacognitive Awareness of Reading Strategies Inventory (MARSI)	✓	-	-	✓	-	-	-	-	✓
36. Metacognitive experiences	-	✓	-	-	-	-	-	✓	✓
37. Metacognitive Interview (Lu, 1995)	✓	-	✓	-	-	-	-	-	✓
38. Metacognitive Interview (MCI) (Lefevre, 1995)	-	-	-	-	✓	✓	-	✓	✓
39. Metacognitive Knowledge in Mathematics Questionnaire (MKMQ)	-	-	-	✓	-	-	-	✓	✓

	Reliability			Validity					
Tools or methods	Internal consistency	Test-retest	Inter-rater	Construct	Face	Content	Ecological	Criterion	**Replicable?**
40. Metacognitive Knowledge Monitoring Assessment (KMA)	✓	-	-	✓	-	-	-	✓	✓
41. Metacognitive Knowledge Questionnaire	✓	-	-	✓	-	-	-	✓	✓
42. Metacognitive Orientation Learning Environment Scale – Science (MOLE-S)	✓	-	-	✓	-	-	-	-	✓
43. Metacognitive Questionnaire (Metallidou and Vlachou, 2010)	✓	✓	-	-	-	-	-	-	✓
44. Metacognitive Questionnaire (Okamoto & Kitao, 1992)	✓	-	-	-	-	-	-	-	✓
45. Metacognitive Skills and Knowledge Assessment (MSA)	✓	-	-	-	-	-	-	✓	✓
46. Metacognitive skills and metacognitive development questionnaire	✓	-	-	-	-	-	-	-	x
47. Metacognitive Strategies (MSTRAT)	✓	-	-	-	-	-	-	✓	✓
48. Metacomprehension Strategy Index (MSI)	✓	-	-	-	-	-	-	✓	✓
49. Motivated Strategies for Learning Questionnaire (MSLQ)	✓	-	-	-	-	✓	-	-	✓
50. Multi method assessment of meta-cognitive behaviours	-	-	✓	-	-	-	-	-	✓
51. Multi-Method Interview (MMI)	✓	-	-	-	✓	-	-	-	✓
52. Observation (CASE@KS1)	-	-	✓	-	-	-	-	-	✓
53. Observational tools for assessing metacognition & self-regulated learning (CHILD 3-5 and C.IND)	✓	-	✓	-	-	-	✓	-	✓
54. Original standardized test for metacognition	-	-	✓	-	-	-	-	-	✓
55. Paper and pencil assessment	✓	-	-	-	-	✓	-	-	✓
56. Private speech coding	-	-	✓	-	-	-	-	-	✓
57. Problem solving interview	-	✓	✓	-	-	-	-	-	✓
58. Prospective Assessment of Children (PAC)	✓	-	-	-	-	-	-	✓	✓
59. Pupil Views Templates (PVTs)	-	-	✓	-	-	-	-	-	✓
60. Questionnaire about Learning in Mathematics (QLM)	✓	-	-	-	-	-	-	✓	✓
61. Questionnaire about Learning Slovene Language (QLSL)	✓	-	-	✓	-	-	-	-	✓
62. Questionnaire about metacognitive beliefs	✓	-	-	✓	-	-	-	-	✓

	Reliability			Validity					
Tools or methods	Internal consistency	Test-retest	Inter-rater	Construct	Face	Content	Ecological	Criterion	**Replicable?**
63. Questionnaire based on Think Aloud	✓	-	-	-	-	-	-	-	✓
64. Rating Student Self-Regulated Learning Outcomes: A Teacher Scale	✓	-	-	✓	-	-	-	-	✓
65. Reading Strategy use scale (RSU scale)	✓	-	✓	✓	-	-	-	-	✓
66. Retrospective Assessment of Children (RAC)	✓	-	-	-	-	-	-	✓	✓
67. Retrospective Questionnaire Interview (RQI)	-	✓	-	-	-	-	-	-	✓
68. Self Regulated Learning Scale (SRL)	✓	-	-	✓	-	-	-	-	✓
69. Self report metacognitive learning strategies	✓	-	-	-	-	-	-	-	✓
70. Self-Assessment in Metacognitive Comprehension Strategies Reading Survey	-	✓	-	-	-	-	-	-	✓
71. Self-Directed Learning Instrument	✓	-	✓	✓	-	-	-	-	✓
72. Self-Efficacy and Metacognition Learning Inventory – Science (SEMLI-S)	✓	-	-	✓	-	-	-	-	✓
73. Self-efficacy for Learning Form (SELF)	✓	-	-	✓	-	-	-	✓	✓
74. Self-Regulated Learning Strategies Measurement Questionnaire	✓	-	-	-	-	-	-	-	✓
75. Self-report for cognitive and metacognitive learning strategies	✓	-	-	-	-	-	-	-	✓
76. State Metacognitive Inventory	✓	-	-	✓	-	-	-	-	✓
77. Strategy card sort, individual interviews	-	-	-	-	-	-	-	-	x
78. Strategy knowledge in the domain of Chemistry	-	-	✓	-	-	✓	-	-	✓
79. Swanson Metacognitive Questionnaire (SMQ)	✓	-	✓	-	-	-	-	-	✓
80. Task based interview	-	-	✓	-	-	-	-	-	✓
81. Teacher Rating (Sperling et al. 2002)	-	-	-	-	-	-	-	✓	✓
82. The Teacher Rating (Desoete, 2008)	✓	✓	✓	✓	-	-	-	✓	✓
83. Think About Reading Index (TARI)	-	-	-	✓	-	✓	-	-	✓
84. Think Aloud Protocol(s) (TAP/TAPs)	✓	-	✓	✓	-	-	-	-	✓

	Reliability			Validity					
Tools or methods	Internal consistency	Test-retest	Inter-rater	Construct	Face	Content	Ecological	Criterion	**Replicable?**
85. Worksamples Interview	-	✓	✓	-	-	-	-	-	✓
86. Würzburg Metamemory Test	✓	✓	-	-	-	-	-	✓	✓

The final number of included tools is 81. Although five methods or tools were excluded at this final stage, this only led to three records being excluded from the final total including citation search additions, this is because Desoete (2009) also cites other tools or methods (The Teacher Rating) so therefore had to remain included, and Fortunato, Hecht, Tittle, and Alvarez (1991) had been added in as a citation search so its exclusion was reflected in the numbers given there.

Summary of findings relating to the methods used

Summarising and describing the results of the review with 153 included records was undertaken using synthesis tables to identify patterns in data and then a narrative synthesis to describe the key themes and findings. These relate to the issues identified in the literature about the assessment of meta-cognition and in particular the types of methods used (see Table 1 and Appendix B for the full classification), the use of tools across multiple age groups and information about the reported reliability and validity of the methods and tools. The key findings of this review include:

- The prevalence of self-report measures (including questionnaires and surveys), more than 50% of the included records.
- Each of the included tools and methods (with data from all of the included records for each tool or method) appear in no more than three of the five age groups other than PVTs which have been used in four out of the five age groups (4 years up to 14 years).
- Self-report measures have only been used with students over the age of 7 years in the included records (see Figure 3).
- Purely observation-based methods have only been used with students aged 11 years and under.
- Clarity about the literacy demands required to understand and to complete self-report measures, alongside the related potential implications for using self-report to assess younger students.
- The majority of these assessments in education are based in the subjects of Mathematics, Literacy (first language) and Science (see Table 3).
- Information regarding reliability and validity is not always provided, or reported accurately.
- The definition of metacognition relates not only to the outcomes of a study but is also intrinsically linked to the tool or method and how it measures or assesses metacognition. How you test is what you get (Desoete, 2008), but that how you define metacognition is also what you get and influences how you test.
- Definitions of metacognition can be linked to the type of tool or method and exploring the links (or lack of them) between the definition of the concept being measured and what the tool actually seems to measure. This is particularly related categories of online and offline methods.

Examining individual categories reveals some interesting patterns relating to age groups, these are illustrated in Table 3. Self-reports, questionnaires and surveys have mainly been used with students over the age of 7 years, no doubt related to the literacy demands that these measures potentially involve. In contrast to this observational methods and interview have been used with participants aged 3-7 years. Task based methods have also been used with the 5-7 years age group but there are not as many examples of these. Pupil Views Templates (PVTs) have the widest range in terms of age and appear in four out of the five possible age groups.

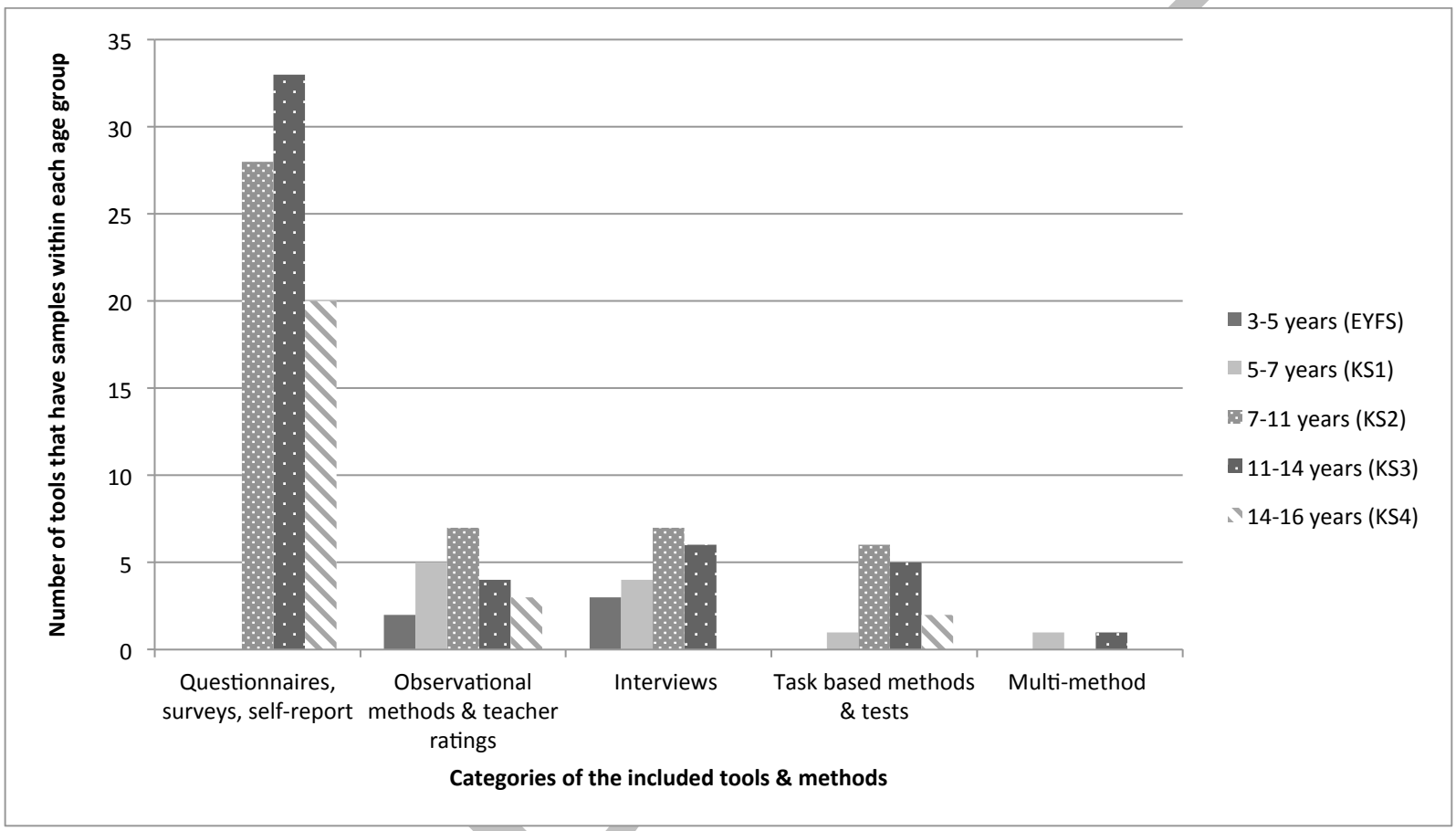

Figure 3:

Age groups covered (NB tools were used across multiple age groups)

Table 3:

Additional subject focus, where specified (total = 81 tools)

Method type	Questionnaires, surveys, self-report	Observational methods and teacher ratings	Interviews	Task-based methods and tests	Multi-method tools
Mathematics	22%	0%	9%	22%	50%
Literacy (first lang.)	20%	0%	18%	0%	0%
Science	6%	10%	0%	11%	0%
Computer/ internet	4%	0%	0%	0%	0%
Physical education	4%	0%	0%	0%	0%
Religious education	2%	0%	0%	0%	0%
Language learning	2%	0%	0%	0%	0%
History	2%	0%	0%	0%	0%
Multiple subjects	10%	20%	0%	11%	0%
No additional focus	28%	70%	73%	56%	50%
Totals	49 tools	10 tools	11 tools	9 tools	2 tools

Defining metacognition: method and is the measure online or offline?

As previously discussed, defining metacognition and its associated concepts is no easy task. It is important to recognise that different groups of tools and particular techniques and methods can define metacognition in very different ways. For example, two self-report measures the MARSI and the MAI (both inventories) both have similar definitions of metacognition based on the reflection on and monitoring of learning, including understanding of learning and an individuals' control of their own learning. In contrast records concerning TAPs often define metacognition in relation to its relevance as a predictor of learning and also makes the same distinction as research using PVTs between metacognitive knowledge and metacognitive skilfulness. Related to this is whether or not it is "administered either prospectively,

concurrently, or retrospectively to performance on a learning or problem-solving task" (Desoete, 2009, p. 436). Examples of prospective tools in this review are the IMSR, Metacognitive ability self-report questionnaire, PAC and Metacognitive Awareness Inventory. Closely related to this debate is the distinction between online and offline methods, what they measure and how as well as the different tools or methods in each category and why they fit into it (Saraç & KaraKelle, 2012; Tillema, van den Bergh, Rijlaarsdam, & Sanders, 2011).

Concurrent methods include TAPs, which is also commonly described as an online technique (Desoete, 2007; Mateos, Martín, Villalón, & Luna, 2008). However as Mateos et al. (2008, p. 695) rightly point out, "while think-aloud protocols are considered one of the most effective tools we have for gaining access to the online cognitive processing of readers and writers, they have certain well-known limitations (e.g., Ericsson & Simon, 1993)." There is room for further debate here, as it could be argued that as soon as a researcher asks a participant to stop, think about and articulate out loud the processes behind their learning that they are actually being forced to be retrospective so the previously presumed [on-line] "reflection-in-action" (Schön, 2002) becomes [offline] reflection-on-action when a student is asked to stop and think aloud. This reflection and its subsequent influence on learning via self-regulatory processes could mean that TAPs are indeed and can remain concurrent throughout the process but this would depend on the tightness of the feedback loop when a learner reflects on their own learning. The degree to which forced reflection on their learning made 'aloud' then makes it retrospective and then how the reflection then does or does not influence their behavior in the remainder of the task requires significant consideration. Other examples of retrospective tools or methods include the RAC and the majority of the included interviews and task-based methods.

Some implications

This synthesis of tools and methods used to measure metacognition in school-aged children is important for wider research on metacognition, as there is not a current review in this area looking systematically at the assessment of metacognition. This review has raised important questions, such as about the age groups with which different methods of assessing metacognition are used.

There are wider debates about the age at which metacognition is present. This is clearly contestable, as we found twelve tools or methods purporting to assess metacognition in participants aged 4 – 7 years, indeed nine studies from seven tools or methods assessing metacognition or closely associated concepts in the youngest age group of 3-5 years. Evidence gathered by Wall (2008) indicates that evidence of metacognitive skilfulness, as gathered using PVTs, appears at an earlier age than previously thought, in children as young as 4 and 5 years old. In contrast, Bartsch, Horvath, and Estes (2003) discuss the difficulties that children of this age have in recognizing how and when knowledge is acquired and Kuhn (1999) argued that metacognitive knowledge could be present at a much younger age than metacognitive skilfulness, which she states does not develop until aged 10-12. Similar to Wall (2008), Leutwyler (2009, p. 112) makes reference to children aged three showing "the first roots of metacognition" and Whitebread et al. (2009) have observed young children showing emergent metacognitive behaviours. The relationship of method to finding may be crucial.

From this review we can also see how tools or methods have changed and been adapted, sometimes to form completely new tools. For example, Wolters (1996) describes a conditional knowledge questionnaire which is adapted from two other tools: the IRA and the MSLQ. The IRA is again mentioned by Schmitt and Sha (2009) when discussing the IMA which is also in part based on the IRA. In addition there are crucial connections between how metacognition is defined in relation to a tool or method and how this definition is then linked to what is being measured. It is important in evaluating the findings of metacognitive assessments to understand what a particular tool or method purports to measure, how this related to the type of tool and the data collected to ensure it is well aligned with the definition of metacognition adopted. This alignment or congruence of definition, of tool, findings resulting from its use with wider claims made about metacognition are essential for the further development of the field.

Appendix A

Search strategy for all databases for searches conducted on 15.11.2012

Database & provider		Search string	Limits applied	n	n - duplicates
Australian Education Index (AEI)	Pro Quest	ab(metacognit* OR meta-cognit*) AND ab(measure OR assess* OR evaluate OR evaluat*) AND ab(student OR pupil OR school OR child OR children)	**Date:** After 1 January 1992	225	207
British Education Index (BEI)	Pro Quest	ab((metacognit* OR meta-cognit*)) AND ab(measure) OR ab(assess*) OR ab(evaluate OR evaluat*) AND ab(student OR pupil OR school OR child OR children)	**Date:** After January 01 1992; **Language:** English; **Age group:** Adolescents (13-17), All children, Children (0-12 years), Infants (0-2), Pre-school children (2-4/5), Young children (0-8)	234	233
ERIC	Pro Quest	ab(metacognit* OR meta-cognit*) AND ab(measure OR assess* OR evaluate OR evaluat*) AND ab(student OR pupil OR school OR child OR children)	**Date:** After January 01 1992**; Language:** English**; Education level:** Early childhood education, Elementary education, Elementary secondary education, Grade 1, Grade 10, Grade 11, Grade 12, Grade 2, Grade 3, Grade 4, Grade 5, Grade 6, Grade 7, Grade 8, Grade 9, High schools, Intermediate grades, Junior high schools, Kindergarten, Middle schools, Preschool education, Primary education, Secondary education	397	266
First Search	Article First	(kw: metacognit* OR kw: meta-cognit*) and (kw: measure OR kw: assess* OR kw: evaluate OR kw: evaluat*) and (kw: student OR kw: pupil OR kw: school OR kw: child OR kw: children)	**Date:** Yr 1992-2012	17	6
First Search Journal Articles	ECO	(kw: metacognit* OR kw: meta-cognit*) and (kw: measure OR kw: assess* OR kw: evaluate OR kw: evaluat*) and (kw: student OR kw: pupil OR kw: school OR kw: child OR kw: children)	**Date:** Yr 1992-2012	282	147
Psych Articles	Ebsco-host	AB (metacognit* OR meta-cognit*) AND AB (measure OR assess* OR evaluate OR evaluat*) AND AB (student OR pupil OR school OR child OR children)	**Year of publication:** from 1992 – 2012; **Age:** Childhood (Birth – 12 years)**;** School age (6-12 Years)**;** Adolescence (13-17 years)	17	0
PsycINFO	Ebsco-host	AB (metacognit* OR meta-cognit*) AND AB (measure OR assess* OR evaluate OR evaluat*) AND AB (student OR pupil OR school OR child OR children)	**Year of publication:** from 1992 – 2012; **Age:** Childhood (Birth – 12 years); School age (6-12 Years)**;** Adolescence (13-17 years)**;** Preschool age (2-5 years)	624	615
Web of Knowledge	Thomson Reuters	Topic=(metacognit* OR meta-cognit*) AND Topic=(measure OR assess* OR evaluate OR evaluat*) AND Topic=(student OR pupil OR school OR child OR children)	**Refined by:** Languages=(ENGLISH) Timespan=1992-01-01 - 2012-11-15. Databases=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH. Lemmatization=On	925	615
			Total:	2721	2089

Appendix B

Summary table

Tool number and name	Primary Citation[5]	Type of tool	Stage of schooling (according to UK conventions)				
			EYFS (3-5 years)	KS1 (5-7 years)	KS2 (7-11 years)	KS3 (11-14 years)	KS4 (14-16 years)
1. Bandura's Self Efficacy for Self-Regulated Learning Scale	Zimmerman, Bandura, and Martinez-Pons (1992)	Self report				✓	✓
2. CDR (Cognitive Developmental aRithmetics test)	Desoete and Roeyers (2006a)	Self report (test)			✓		
3. Classroom Coding System	Stright, Neitzel, Sears, and Hoke-Sinex (2001)	Observation	✓	✓	✓		
4. Clinical Interview	(Pappas, Ginsburg, & Jiang, 2003)	Interview	✓	✓			
5. Computer based measure of metacognitive skilfulness	Veenman, Wilhelm, and Beishuizen (2004)	Computerised			✓	✓	
6. Concept maps	Ritchhart, Turner, and Hadar (2009)	Task based (Concept map)			✓	✓	✓
7. Conditional knowledge (part of a questionnaire)	Wolters (1996)	Questionnaire				✓	
8. Constructivist Internet based Learning Environment Survey (CILES)	Wen, Tsai, Lin, and Chuang (2004)	Self report (internet based)					✓
9. EPA2000 (Evaluation and Prediction Assessment)	Desoete and Roeyers (2006b)	Computerised measure			✓		
10. Epistemic metacognition measure	Mason, Boldrin, and Ariasi (2010)	Retrospective Interview				✓	
11. General Studies Metacognitive Orientation Scale (GSMOS)	Thomas and Au Kin Mee (2005)	Self report			✓		
12. Goal Orientation and Learning Strategies	Dowson and McInerney	Self report				✓	✓

[5] The citation from which most of the methodological information was extracted from in this review. The age ranges given are taken from all of the records citing a particular tool

Tool number and name	Primary Citation[5]	Type of tool	Stage of schooling (according to UK conventions)				
			EYFS (3-5 years)	KS1 (5-7 years)	KS2 (7-11 years)	KS3 (11-14 years)	KS4 (14-16 years)
Survey (GOALS-S)	(2004)						
13. Index of Metacognitive Awareness about Writing (IMAW)	De Kruif (2000)	Self report			✓	✓	
14. Index of Reading Awareness (IRA)	Jacobs and Paris (1987)	Self report			✓	✓	✓
15. Index of Science Reading Awareness (ISRA)	Yore, Craig, and Maguire (1998)	Self report			✓	✓	
16. Individual interview – strategy use and metacognition	Throndsen (2011)	Interview			✓		
17. Integrated Learning Assessment	Silver, Hansen, Herman, Silk, and Greenleaf (2011)	Questionnaire				✓	✓
18. Interview about Metacognitive Awareness (IMA)	Schmitt and Sha (2009)	Interview			✓	✓	
19. Interview from Munich Longitudinal Study on the Genesis of Individual Competencies	Lockl and Schneider (2006)	Interview	✓				
20. Inventory of Metacognitive Self-Regulation (IMSR)	Howard et al. (2000)	Self report			✓	✓	✓
21. Junior Metacognitive Awareness Inventory (JrMAI)	Sperling et al. (2002)	Self report			✓	✓	✓
22. Knowledge and skills questionnaire	de Jager, Jansen, and Reezigt (2005)	Questionnaire				✓	
23. Learning strategies assessed by journal writing	Glogger, Schwonke, Holzäpfel, Nückles, and Renkl (2012)	Task based (Journal writing)				✓	
24. Learning Through Reading Questionnaire (LTRQ)	Butler, Cartier, Schnellert, Gagnon, and Giammarino (2011)	Questionnaire				✓	✓
25. Metacognition Applied to Physical Activities Scale (MAPAS)	Settanni, Magistro, and Rabaglietti (2012)					✓	
26. Metacognition of Nature of Science Scale (MONOS)	Peters (2008)	Self report survey				✓	
27. Metacognition Scale	Yildiz et al. (2009)	Self report			✓	✓	
28. Metacognitive Processes in Physical Education Questionnaire (MPIPEQ) – 8	Theodosiou, Mantis, and Papaioannou (2008)	Questionnaire			✓	✓	✓

Tool number and name	Primary Citation[5]	Type of tool	Stage of schooling (according to UK conventions)				
			EYFS (3-5 years)	KS1 (5-7 years)	KS2 (7-11 years)	KS3 (11-14 years)	KS4 (14-16 years)
scales from							
29. Metacognitive ability self-report questionnaire	Panaoura and Philippou (2007)	Self report			✓		
30. Metacognitive Attribution Assessment (MAA)	Desoete, Roeyers, and Buysse (2001)	Rating scale			✓		
31. Metacognitive Awareness Inventory (MAI)	Schraw and Dennison (1994)	Self report				✓	✓
32. Metacognitive Awareness of Reading Strategies Inventory (MARSI)	Mokhtari and Reichard (2002)	Self report			✓	✓	✓
33. Metacognitive experiences	Dermitzaki and Efklides (2001)	Self report			✓	✓	✓
34. Metacognitive Interview	Lu (1995)	Interview			✓	✓	
35. Metacognitive Interview (MCI)	Lefevre (1995)	Interview			✓	✓	
36. Metacognitive Knowledge in Mathematics Questionnaire (MKMQ)	Efklides and Vlachopoulos (2012)	Questionnaire				✓	✓
37. Metacognitive Knowledge Monitoring Assessment (KMA)	Tobias and Everson (1996)	Paper and pencil or computerised assessment			✓	✓	
38. Metacognitive Knowledge Questionnaire	Metallidou and Vlachou (2010)	Teacher rating			✓	✓	
39. Metacognitive Questionnaire	Okamoto and Kitao (1992)	Questionnaire			✓		
40. Metacognitive Questionnaire	Patnaik (2009)	Questionnaire			✓		
41. Metacognitive Orientation Learning Environment Scale – Science (MOLE-S)	Thomas (2003)	Self report				✓	✓
42. Metacognitive Questionnaire	Swanson and Trahan (1996)	Questionnaire			✓		
43. Metacognitive Skills and Knowledge Assessment (MSA)	Desoete et al. (2001)	Self report			✓		
44. Metacognitive Strategies (MSTRAT)	Roeschl-Heils, Schneider, and van Kraayenoord (2003)					✓	

Tool number and name	Primary Citation[5]	Type of tool	Stage of schooling (according to UK conventions)				
			EYFS (3-5 years)	KS1 (5-7 years)	KS2 (7-11 years)	KS3 (11-14 years)	KS4 (14-16 years)
45. Metacomprehension Strategy Index (MSI)	Schmitt (1990)[6]	Self report			✓	✓	
46. Motivated Strategies for Learning Questionnaire (MSLQ)	Pintrich and De Groot (1990)	Questionnaire			✓	✓	✓
47. Multi method assessment of meta-cognitive behaviours	Shamir, Mevarech, and Gida (2009)	Multi method	✓				
48. Multi-Method Interview (MMI)	Wilson (1999)	Multi method				✓	
49. Observation (CASE@KS1)	Larkin (2006)	Observation		✓			
50. Observational tools for assessing metacognition and self-regulated learning • C.Ind.Le • CHILD 3–5	Whitebread et al. (2009)	Observation	✓				
51. Original standardized test for metacognition	Kreutzer, Leonard, and Flavell (1975)	Interview		✓	✓		
52. Paper and pencil assessment	Neuenhaus, Artelt, Lingel, and Schneider (2011)	Test			✓		
53. Private speech coding	Daugherty and Logan (1996)	Observation		✓			
54. Problem solving interview	Carr and Jessup (1995)	Task based (interview)		✓			
55. Prospective Assessment of Children (PAC)	Desoete (2007)	Self report			✓		
56. Pupil Views Templates (PVTs)	Wall (2008)	Self report (mediated interview)	✓	✓	✓	✓	
57. Questionnaire about Learning in Mathematics (QLM)	Peklaj and Vodopivec (1998)	Questionnaire			✓		
58. Questionnaire about Learning Solvene Language (QLSL)	Peklaj (2001)	Questionnaire			✓		

[6] Would not have been included originally (date and not empirical data) but data extraction from the first paper (referred to as the first one with the MSI tool in the additional references)

Tool number and name	Primary Citation[5]	Type of tool	Stage of schooling (according to UK conventions)				
			EYFS (3-5 years)	KS1 (5-7 years)	KS2 (7-11 years)	KS3 (11-14 years)	KS4 (14-16 years)
59. Questionnaire about metacognitive beliefs	van der Zee, Hermans, and Aarnoutse (2006)	Questionnaire			✓		
60. Questionnaire based on Think Aloud	Schellings (2011)	Questionnaire					✓
61. Rating Student Self-Regulated Learning Outcomes: A Teacher Scale–RSSRL	Zimmerman and Martinez-Pons (1988)	Teacher rating scale			✓	✓	✓
62. Reading Strategy use scale (RSU scale)	Pereira‐Laird and Deane (1997)	Self report			✓	✓	
63. Retrospective Assessment of Children (RAC)	Desoete (2007)	Self report			✓		
64. Retrospective Questionnaire Interview (RQI)	Short (2001)	Interview				✓	
65. Self Regulated Learning Scale (SRL)	Prupas (1995)					/	
66. Self report metacognitive learning strategies	Leutwyler (2009)	Self report					✓
67. Self-Assessment in Metacognitive Comprehension Strategies Reading Survey (SAMS)	Pinto (2009)	Self report				✓	
68. Self-Directed Learning Instrument	Hwang (1999)	Structured observation	✓		✓		
69. Self-Efficacy and Metacognition Learning Inventory – Science (SEMLI-S)	Thomas, Anderson, and Nashon (2008)	Self report			✓	✓	
70. Self-efficacy for Learning Form (SELF)	Zimmerman and Kitsantas (2005)	Self report				✓	
71. Self-Regulated Learning Strategies Measurement Questionnaire (SRLSMQ)	Eom (1999)	Questionnaire SR				✓	
72. Self-report for cognitive and metacognitive learning strategies	Wolters (1999)	Self report				✓	✓
73. State metacognitive inventory	O'Neil and Abedi (1996)	Self report			✓	✓	✓
74. Strategy knowledge in the domain of Chemistry	Scherer and Tiemann (2012)	Task based (ranking methodologies)					✓
75. Swanson Metacognitive Questionnaire (SMQ)	Swanson (1990)	Questionnaire			✓	✓	
76. Task based interview	Carr and Jessup (1997)	Task based (interview)		✓			
77. Teacher Rating	Sperling et al. (2002)	Teacher rating			✓	✓	
78. The Teacher Rating	Desoete (2008)	Teacher rating			✓		
79. Think About Reading Index (TARI)	Schreiber (2003)	Self report			✓	✓	

Tool number and name	Primary Citation[5]	Type of tool	Stage of schooling (according to UK conventions)				
			EYFS (3-5 years)	KS1 (5-7 years)	KS2 (7-11 years)	KS3 (11-14 years)	KS4 (14-16 years)
80. Think Aloud Protocol(s) (TAP/TAPs)	Veenman, Kok, and Blöte (2005)	Observation			✓	✓	✓
81. Worksamples Interview	van Kraayenoord and Paris (1997)	Interview			✓		
82. Würzburg Metamemory Test	van Kraayenoord and Schneider (1999)	Test			✓		

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* = Records included in the systematic review that are cited in this paper

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